INVESTIGATIONS ON THE JURASSIC FLORA OF THE RAJMAHAL HILLS, INDIA

2. ON A NEW SPECIES OF *PTILOPHYLLUM*, *P. SAHNII* FROM AMARJOLA IN AMARAPARA REGION

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ABSTRACT—A new species of the cycadean frond *Ptilophyllum*, *P. sahnii* sp. nov. from the Middle Jurassic of the Rajmahal Hills is described on the basis of its epidermal studies. The epidermal cells of the stomatal and non stomatal bands are not only isodiametric in shape but do not possess even the sinuous walls which are usually found in Bennettitalean fronds. The stomata are characteristically of the syndetocheilic type.

INTRODUCTION

WHILE he was engaged in the study of the geology of the Cutch in India, John Morris established the genus *Ptilophyllum* in the year 1840. These fronds were characterised by features such as pinnate disposition of closely set linear and lanceolate pinnae which were more or less elongate, imbricate at the base and attached obliquely on the rachis. The base was semicircular or rounded, veins equal, slender and parallel. He founded two different species from his collection, namely *P. cutchense* and *P. acutifolium*.

Since then more than two dozen species of the genus have been described from the Jurassic and lower Cretaceous localities throughout the world. The Indian fronds dominate with as many as sixteen species. Oldham and Morris had adopted the name *Palaeozamia* for similar fronds during their investigations of the fossil flora of the Rajmahal Series in the Rajmahal Hills, Bihar in the year 1863; but Feistmantel who followed them preferred the name *Ptilophyllum* and added some more species to the genus from different Indian localities. Some sixteen species are now known from India. This, however, includes two species, *P. sakrigaliensis* Sah (1958) and *P. horridum* Roy (1963) of which only the abstracts have appeared and full descriptions are awaited. Most of the species founded by recent workers are based on epidermal studies as indeed the cuticular structures of thirteen out of sixteen have been described, the two exceptions being the earlier species of Feistmantel namely *P. tenerrimum* (1877) and *P. brachyphyllum* (1877).

It seems Bornemann (1856) was the first who paid attention to the cuticular studies of the fossil cycadean fronds, though the real significance of the epidermal and cuticular investigations came to be realised during the present centuary when workers like Thomas, Bancroft, Florin, Harris etc., made important contribution. Harris writes "I have laboured

the cuticle because it illustrates a respect in which fossil botany has grown up. Cuticle adds considerably to your work and if you study it properly you will quarter your output of new species". In 1913 Thomas and Bancroft investigated the cuticles of the cycadean fronds and said "In the cycadean alliance we find some characters which have undergone comparatively little modifications in the ages which have elapsed between the Jurassic times and the present day and we are considerably entitled to regard stomatal structures as being the expressions of ancestral characters rather than of purely local and temporary conditions of environments".

Jacob, Bose and Vishnu-Mittre have worked out the cuticles of Indian Ptilophyllums from different upper Gondwana horizons and have been able to establish new species on the basis of their cuticular studies in them. In India, Sahni studied the cuticle of fossil plants as early as 1923 but the other workers have taken interest only recently both in the investigations of fossil and living plants (Chowdhury 1936; Rao, 1939; Bose, 1953, 1958; Jacob and Jacob, 1954; Mittre, 1956; Gupta, 1957). The present material was collected by the senior author in the year 1956 from Amarjola in the Rajmahal Hills, Bihar. The fronds are well preserved, though fragmentary, on a dark brown fragile rock. The cuticular studies of this material have been made both by reflected light and transfer peels prepared with the help of adhesives like the Durofix and the Quickfix. The peelings were stained with safranin.

DESCRIPTION

Type specimen no. K 1/Raj. A. Gupta Coll., Amarjola, Amarapara region, Rajmahal Hills, India. *Ptilophyllum sahnii* sp. nov. Gupta and Sharma.

Diagnosis.—Frond pinnate, habit Ptilophyllum amarjolense like; attachment of pinnae oblique, alternate, approximate on the upper surface of rachis; pinnae thick, leathery, short, oval, 0.3-0 ×0.25-0.3 cm: apex obtuse, veins usually eight in number, diverging near the base with bifurcations at all levels.

Upper surface of the pinnae made up of elongated epidermal cells without stomata or papillae; lower cuticle differentiated into stomatal and non stomatal bands; epidermal cells isodiametric with less or no sinuous walls and each having one circular papilla. Stomata transversely oriented and irregularly placed in the stomatal bands; inner walls of subsidiary cells without papillae and outer ones smooth.

External features.—There are three specimens in our collection representing the new species. These are K 1,2,3/Raj. A. and are preserved on fragile, sandy brown rock unlike the hard grey silicified rocks characteristic of many Rajmahal localities. The specimens numbered K. 2 and 3/Raj. A. differ a little in the length and breadth but are otherwise similar in structure.

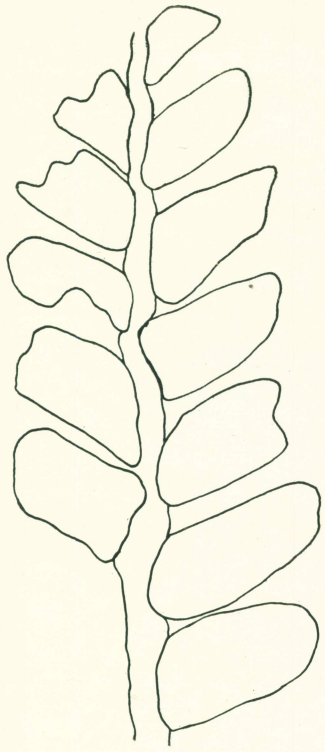
It is a pinnate frond of unknown length. The type specimen is an apical portion, about three centimetre long and 0.6-1.2 broad (Text fig. 1; pl. I, fig.1) The pinnae are short and oval. These are attached obliquely and closely on the upper surface of the rachis. The individual pinnae are attached by their entire bases;

Explanation of Text-Figs. 1-4

Text—fig. 1, 1a. *Ptilophyllum sahnii* sp. nov. Type specimen no. K1/Raj. A. Amarjola, Rajmahal Hills; Gupta Coll. Camera lucida sketch of the frond and a single pinna with bifurcating veins. ×Ca 4

Text—figs. 2,3. Same. Camera lucida drawings of the lower epidermis showing isodiametric papillate cells of the stomatal and non-stomatal bands as well as the stomata. × 150.

Text—fig. 4. Same. Camera lucida drawing of a single stoma to show the guard cells and the subsidiary cells. Note both the walls of the subsidiary cells are thickened while only the outer wall is thickened in the guard cell. × 1000.



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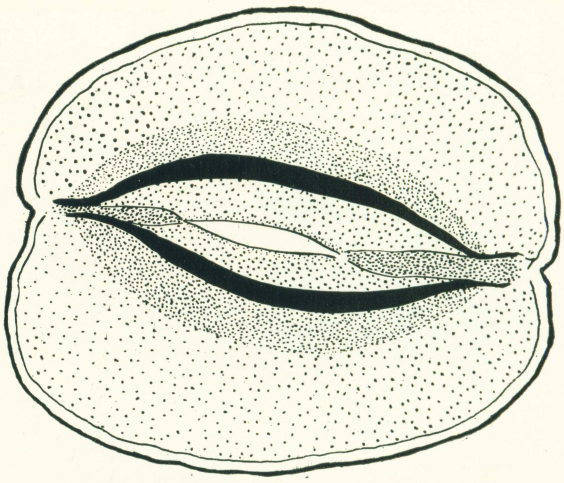

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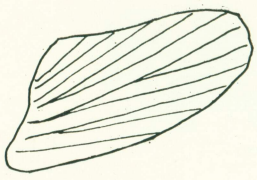

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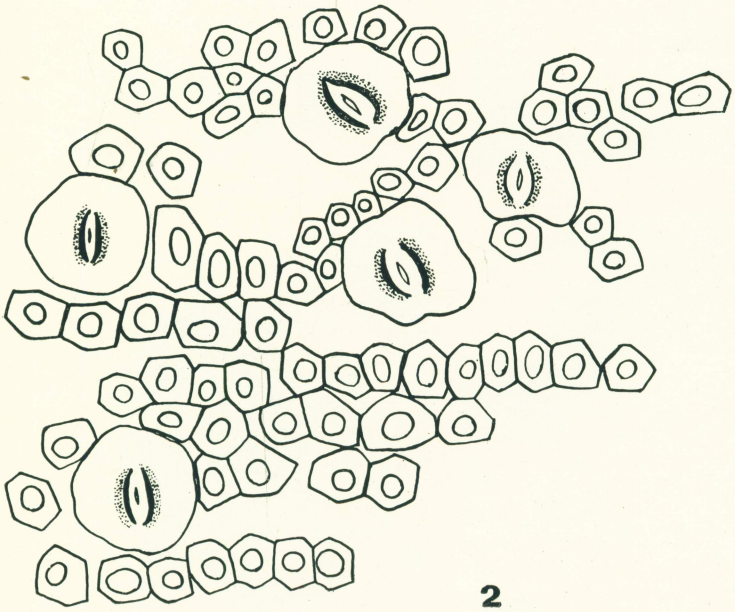

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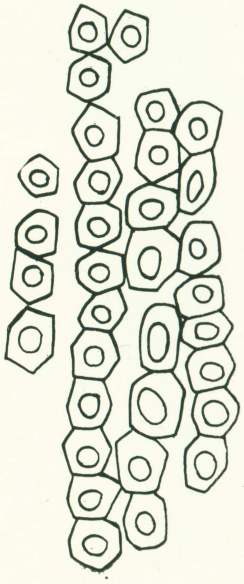

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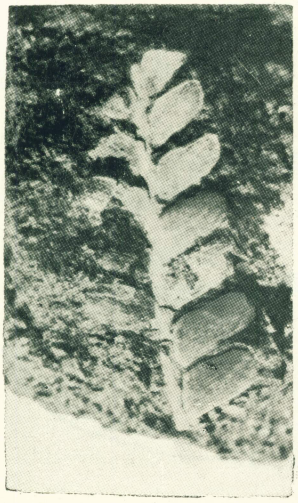
TEXT-FIGS. 1-4



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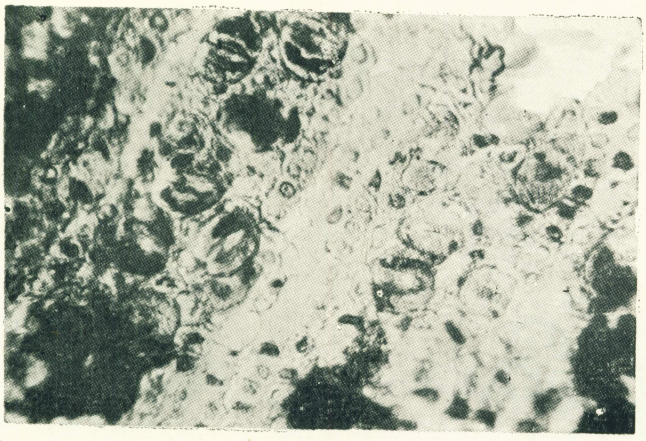

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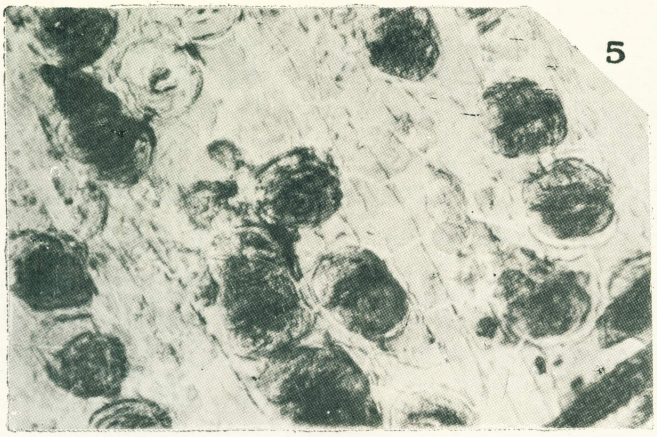

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GUPTA & SHARMA : PTILOPHYLLUM SAHNII S.P. NOV. FROM RAJMAHAL HILLS

their apices being obtuse in shape (Text fig.1). Generally eight veins traverse each pinna, diverging near the base and bifurcating at all levels (Text fig. 1a).

Cuticle.—The upper epidermis of the pinna is made up of elongated cells with less sinuous walls and with tapering ends. There are no stomata on this upper suface. The lower epidermis of the pinna on the other hand can be differentiated into stomatiferous and non stomatiferous bands; the former slightly wider than the latter (Text figs. 2, 2a; pl. fig. 4). The epidermal cells in both these regions, however, are similar being isodiametric in shape with thick walls which hardly show any sinuosity in their outlines (Text figs. 2,2a; pl. figs. 2,4). Each cell is further provided with a large central papilla (Text fig. 2; pl. figs. 4, 6); three or four such cells cover a single vein (Pl. fig. 4). This structure of the epidermal cells provides the diagnostic character of this new species.

The stomata are usually confined only to the stomatal bands; but sometimes they have been seen on the non stomatal region (Text fig. 2). They are usually oriented transversely to the veins but sometimes irregularly placed (Pl. figs 2,3). The distribution of stomata is roughly 140-160 per mm. and 2-4 of these seem to cross transversely a single stomatal band (Pl. figs. 2,4). Each stoma is nearly a rounded structure, measuring 68-80 × 60-72 μ. The two guard cells are elongated, reniform in shape with thick outer wall and thin inner wall enclosing the stomatal aperture (Text fig. 4; pl. fig. 6) The guard cells are surrounded by two broad subsidiary cells, one on each side. Both outer and inner walls of the subsidiary cells are thick; the inner wall is without any papilla (Text fig.4) The stomata are typically bennettitalean in character namely of the syndetocheilic type. The structure of the epidermal cells as well as the stomata differ materially from those of *Ptilophyllum amarjolense* (Pl. fig. 5).

Comparison.—A reference may be made to the two tables accompanying the present paper wherein external as well as internal characters of all the Indian species of *Ptilophyllum* are given. The present species differs from all the known species which have been compared in the genus in some distinct epidermal features, such as the isodiametric epidermal cells with thick non-sinuous walls and with one circular papilla in each of the lower epidermis of the pinna.

Conclusion.—Thomas and Bancroft in 1913 divided the cycads into two sub groups on the basis of epidermal features; one with the epidermal cells having thin and sinuous walls under the Bennettitales; the other with epidermal cells having thick non-sinuous and smooth walls under the Cycadales. It may be interesting to point out that the present mate-

Explanation of Plate 1

1. Type specimen no. K 1/ Raj. A. *Ptilophyllum sahnii* sp. nov. × Ca. 2
2. Same. Lower epidermis showing isodiametric epidermal cells of the non-stomatal and the differently oriented stomata of the two stomatal bands, above and below. × 110.
3. Frond of *P. amarjolense* Bose × Ca. 2.
4. *P. sahnii* sp. nov., lower epidermis showing papillate isodiametric cells of the non-stomatal and stomatal bands with irregularly arranged stomata on the latter. × 110.
5. *P. amarjolense* Bose, Lower epidermis showing non-papillate rectangular cells of the non-stomatal bands and irregular papillate cells of the stomatal bands with stomota. X 110.
6. *P. sahnii* sp. nov., lower epidermis, a single stoma enlarged showing the guard cells with only outer walls thick and non-papillate; subsidiary cells with both outer and inner walls thickened. × 450.
7. *P. amarjolense* Bose, A single stoma enlarged showing non-papillate somewhat less thickened subsidiary cells. × 450.

rial of the Bennettitalean frond shows epidermal cells possessing characters somewhat approaching the latter category namely. epidermal cells are thick and smooth. Not only this but their nature is similar both in the stomatal and non-stomatal bands. Further we have noted this kind of structure in some bracts of the flowers of *Williamsonia* in our collection. The presence or absence as well as the shape of the papillae in their cells also seem to constitute diagnostic features and will help in the classification of these fronds.

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TABLE 1

Showing the external morphological characters of Indian *Ptilophyllum* fro

No.	Species	Frond & attachment of pinnae	Shape & size of pinnae	Base of pinnae	Apex of pinnae
1	*Ptilophyllum acutifolium* Morr.	Pinnate; pinnae oblique, alternate, close on rachis.	Linear, falcate; 0·7-2 × 0·3 cms.	Upper angle round, lower decurrent.	Falciform & accuminate.
2	*P. cutchense* Morr.	Pinnate; pinnae oblique, alternate, close or sparse on rachis.	Short, broad, slightly falcate. 0·5-1 × 0·2 cms.	Both angles round.	Falciform & obtusely accuminate.
3	*P. brachyphyllum*. Fst.	Pinnate; pinnae little oblique, alternate, close on rachis.	Short, broad, length not more than three times the breadth.	Upper angle round, lower decurrent.	Obtuse.
4	*P. tenerrimum*. Fst.	Pinnate; pinnae straight, alternate, close on rachis.	Linear, narrow, straight; size unknown.	Unknown.	Unknown.
5	*P. amarjolense*. Bose.	Pinnate; pinnae little oblique, alternate, close on rachis.	Small, oblong; 0·8-0·9 × 0·2-0·5 cms.	Upper angle round, lower not round.	Round, in apical region & in wide fronds acute.
6	*P. indicum*. Jacob & Jacob.	Pinnate; pinnae oblique, alternate, close on rachis.	Linear, falcate, straight; 1·6-2·6 × 0·17-0·27 cms.	Upper angle round, lower nondecurrent.	Falciform & accuminate.
7	*P. oldhami*. Jacob & Jacob.	Pinnate; pinnae oblique, alternate, close on rachis.	Short, oval; 0·8-0·9 × 0·25-0·3 cms.	Both angles round.	Round.
8	*P. distanse*. (Fst.) Jacob & Jacob.	Pinnate; pinnae oblique, alternate, sparse on rachis.	Linear, narrow, falcate; 1-18. × 0·1-0·17 cms.	Upper angle round, free, lower decurrent.	Falciform & accuminate.
9	*P. jabalpurense*. Jacob & Jacob.	Pinnate; pinnae oblique, opposite, alternate, close on rachis.	Linear, very narrow, straight; 0·7-1.3 × 0·12 cms.	Upper lobe round, free, lower not round.	Round.
10	*P. nipanica*. Mittre	Pinnate; pinnae oblique, alternate, imbricate on rachis.	Short, broad, falcate, size unknown.	Both angles round.	Falcate, pointed apex.
11	*P. gladiatum*. Bose.	Pinnate; pinnae oblique alternate, close on rachis.	Gladius like; 1-1·5 × 0·3 cms.	Upper base angle round, lower less round.	Acute.
12	*P. institacalum*. Bose & Sukhdev.	Pinnate; pinnae oblique, alternate, close on rachis.	Small, straight; 1-1·2 × 0·2-0·25 cms.	Upper angle round, lower concealed by lower pinna	Obtusely pointed.
13	*P. sakrigaliensis*. Sah.	Pinnate; pinnae oblique, alternate, sparse on rachis.	Linear, lanceolate; size unknown.	Unknown.	Unknown.
14	*P. horridum*. Roy.	Pinnate; pinnae little oblique, alternate on rachis.	Unknown.	Unknown.	Unknown.
15	*P. guptai* Sharma	Pinnate; pinnae little oblique, alternate, close on rachis.	Linear, straight; 1·7-2·6 × 0·3-0·4 cm.	Round.	Acute.
16	*P. sparsifolium* Sharma	Pinnate; pinnae, oblique, alternate, sparse on rachis.	Linear, falcate; 2·3-1 × 0·25-0·15 cm.	Round.	Acute.
17	*P. sahnii*. Gupta & Sharma n.sp.	Pinnate; pinnae oblique, alternate, close on rachis.	Small, oval; 0·3-0·6 × 0·25-0·3 cms.	Both angles round.	Obtuse.

TABLE 1

e external morphological characters of Indian *Ptilophyllum* fronds.

e & size of pinnae	Base of pinnae	Apex of pinnae	Venation	Locality & horizon	Remarks
alcate; ·3 cms.	Upper angle round, lower decurrent.	Falciform & accuminate.	7-10, nearly parallel with bifurcations.	Kach; (Oolite).	
oad, slightly falcate. ·2 cms.	Both angles round.	Falciform & obtusely accuminate.	7-8, radiating from base with bifurcations.	Kukurbit (Kach); Oolite.	
oad, length not more ee times the breadth.	Upper angle round, lower decurrent.	Obtuse.	Unknown, nearly parallel.	Unknown.	
narrow, straight; size n.	Unknown.	Unknown.	Unknown.	Unknown.	
blong; ×0·2-0·5 cms.	Upper angle round, lower not round.	Round, in apical region & in wide fronds acute.	8-9, nearly parallel with bifurcations.	Amarjola (Rajmahal Hills); Middle Jurassic.	
falcate, straight; ×0·17-0·27 cms.	Upper angle round, lower nondecurrent.	Falciform & accuminate.	3-10, nearly parallel with bifurcations.	Ghuneri (Cutch); Lower Cretaceous.	
val; ×0·25-0·3 cms.	Both angles round.	Round.	Indistinct.	Ghuneri (Cutch); Lower Cretaceous.	
arrow, falcate; ·1-0·17 cms.	Upper angle round, free, lower decurrent.	Falciform & accuminate.	3-7, nearly parallel with bifurcations.	Sharpur River (Jabalpur); Upper Jurassic.	
ery narrow, straight; ×0·12 cms.	Upper lobe round, free, lower not round.	Round.	4-6, indistinct.	Sharpur River (Jabalpur); Upper Jurassic.	
oad, falcate, size un-	Both angles round.	Falcate, pointed apex.	3-5, with bifurcations.	Nipania (Rajmahal Hills); Middle Jurassic.	
ike; ·3 cms.	Upper base angle round, lower less round.	Acute.	Indistinct.	Bansa (Jabalpur); Upper Jurassic.	
raight; ·2-0·25 cms.	Upper angle round, lower concealed by lower pinna	Obtusely pointed.	Indistinct, nearly parallel	Sharpur River (Jabalpur); Upper Jurassic.	
lanceolate; size un-	Unknown.	Unknown.	Unknown.	Sakrigalighat (Rajmahal Hills); Middle Jurassic.	Abstract.
n.	Unknown.	Unknown.	Unknown.	Cutch; Lower Cretaceous.	Abstract.
traight; ×0·3-0·4 cm.	Round.	Acute.	8-9, nearly, parallel, with bifurcations.	Amarjola (Rajmahal Hills); Middle Jurassic.	
alcate; ·25-0·15 cm.	Round.	Acute.	5-6, parallel, with few bifurcations.	Amarjola (Rajmahal Hills); Middle Jurassic.	
al; ×0·25-0·3 cms.	Both angles round.	Obtuse.	8-9, radiating from base, with bifurcations.	Amarjola (Rajmahal Hills); Middle Jurassic.	

TABLE 2

Showing Epidermal features of some Indian *Ptilophyllum*

No.	Species	Epidermis			Distribution
		Upper epidermic	Lower epidermis		
			Non stomatal region	Stomatal region	
1	*Ptilophyllum acutifolium* Morr.	Irregular, delicate, sinuous, non papillate.	2-4, sinuous, oval papillate.	Irregular, sinuous, hollow papillate.	175-200 per sq. m 2-3 in a band.
2	*P. cutchense* Morr.	Irregular, delicate, sinuous, non papillate.	2-4, sinuous, hollow papillate.	Irregular, sinuous, hollow papillate.	2-4 in a band.
3	*P. amarjolense* Bose.	Elongate, sinuous, non papillate.	3-4, sinuous, elogated, non papillate.	Irregular, sinuous, papillate.	3-5 in a band.
4	*P. indicum* Jacob & Jacob.	Irregular, sinuous, non papillate.	2-4, sinuous, elongated, non papillate.	Irregular, sinuous, papillate.	160-180 per sq. m 2-4 in a band.
5	*P. oldhami* Jacob & Jacob.	Squarish, sinuous, non papillate.	Irregular, sinuous, non papillate.	Irregular, sinuous, hollow papillate.	3-4 in a band.
6	*P. distanse* (Fst.) Jacob & Jacob.	Not available.	4-5, sinuous, irregular, hollow papillate.	Irregular, sinuous, papillate.	120-125 per sq. m 3-5 in a band.
7	*P. jabalpurense* Jacob & Jacob.	Not available.	Irregular, sinuous, non papillate.	Irregular, sinuous, hollow papillate.	175-180 per sq. m 2-3 in a band.
8	*P. nipanica* Mittre.	Squarish, sinuous, non papillate.	Squarish - rectangular, sinuous, few papillate.	Squarish - rectangular, sinuous, few papillate.	Unknown.
9	*P. gladiatum* Bose.	Rectangular - squarish, sinuous, non papillate.	Irregular, sinuous, non papillate.	Irregular, sinuous, papillate various shaped.	Unknown.
10	*P. institacalum* Bose & Sukhdev.	Squarish - rectangular, sinuous non papillate.	Rectangular, sinuous, papillate.	Rectangular, sinuous, papillate.	Unknown.
11	*P. guptai* Sharma.	Squarish - irregular, sinuous non papillate.	2-3, irregular, sinuous, mostly papillate.	Irregular, sinuous, mostly papillate.	70-75 per sq. mm 2-5 in a band.
12	*P. sparsifolium* Sharma.	Rectangular, sinuous, non papillate.	3-4, irregular, sinuous, non papillate.	Irregular, sinuous non papillate.	60-70 per sq. mm 3-5 in a band.
13	*P. sahnii* Gupta & Sharma n.sp.	Elongated, non sinuous, non papilla.	Isodiametric, thick wall, each with one central circular papillate.	Isodiametric, thick wall, each with one central circular papilla.	138-166 per sq. m 3-4 in a band.

TABLE 2

Showing Epidermal features of some Indian *Ptilophyllum* fronds.

Epidermis		Stomata			
Lower epidermis		Distribution	Shape & size	Guard cells	Subsidiary cells
Non stomatal region	Stomatal region				
2-4, sinuous, oval papillate.	Irregular, sinuous, hollow papillate.	175-200 per sq. mm.; 2-3 in a band.	Round; 45-52×60-62 μ.	Semilunar.	Outer wall looped, each with one or more papillae.
2-4, sinuous, hollow papillate.	Irregular, sinuous, hollow papillate.	2-4 in a band.	Oblong; 36-60×47-70 μ.	Spindle shape, uniform cell wall.	Outer wall smooth, no papillae,
3-4, sinuous, elogated, non papillate.	Irregular, sinuous, papillate.	3-5 in a band.	Round.	Crescent.	Outer wall smooth, no papillae.
2-4, sinuous, elongated, non papillate.	Irregular, sinuous, papillate.	160-180 per sq. mm.; 2-4 in a band.	Round; 50-53×55-60 μ.	Crescent.	Outer wall smooth, one papillae in each.
Irregular, sinuous, non papillate.	Irregular, sinuous, hollow papillate.	3-4 in a band.	Oblong; 66×50 μ.	Crescent.	Outer wall smooth, no papillae.
4-5, sinuous, irregular, hollow papillate.	Irregular, sinuous, papillate.	120-125 per sq. mm.; 3-5 in a band.	Round - oblong; 50-53×60-66 μ.	Reniform, inner wall thin.	Outer wall looped, with papillae.
Irregular, sinuous, non papillate.	Irregular, sinuous, hollow papillate.	175-180 per sq. mm.; 2-3 in a band.	Round - oblong; 36-38×36-66 μ.	Crescent.	Outer wall smooth, no papillae.
Squarish - rectangular, sinuous, few papillate.	Squarish - rectangular, sinuous, few papillate.	Unknown.	Round; 38-51×35-45 μ.	Crescent.	Outer wall smooth, papillate.
Irregular, sinuous, non papillate.	Irregular, sinuous, papillate various shaped.	Unknown.	Oblong.	Curved, crescent.	Outer wall looped, no papillae.
Rectangular, sinuous, papillate.	Rectangular, sinuous, papillate.	Unknown.	Oblong.	Crescent.	Outer wall smooth, no papillae.
2-3, irregular, sinuous, mostly papillate.	Irregular, sinuous, mostly papillate.	70-75 per sq. mm.; 2-5 in a band.	Round; 60-64×64-72 μ.	Reniform, inner wall thin.	Outer wall smooth, no papillae.
3-4, irregular, sinuous, non papillate.	Irregular, sinuous non papillate.	60-70 per sq. mm.; 3-5 in a band.	Roundish; 48-60×48-56 μ.	Reniform, inner wall thick.	Outer wall smooth, no papillae.
Isodiametric, thick wall, each with one central circular papillate.	Isodiametric, thick wall, each with one central circular papilla.	138-166 per sq. mm.: 3-4 in a band.	Round - oblong; 68-80×60-72 μ.	Reniform, inner wall thin.	Outer wall smooth, no papillae.